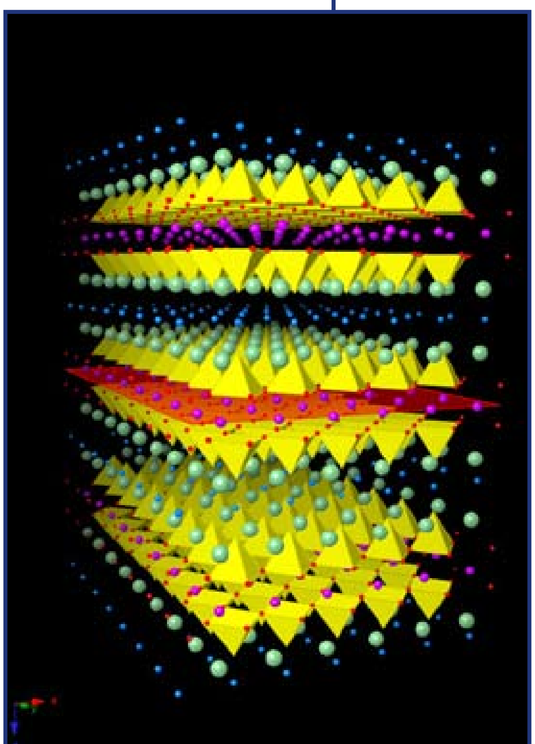
New Understanding of Superconducting Behavior Documented in *Physical Review Letters*

Recent modeling study helps resolve a long-standing debate about the forces influencing electron flow in high-temperature superconductors.



Superconducting materials conduct electricity without loss caused by resistance.

The December 2 issue of *Physical Review Letters* presents the results of investigations into the nature of high-temperature superconductivity by researchers at Oak Ridge National Laboratory, the University of Cincinnati, and the University of Tennessee–Knoxville (2 December 2005 doi:10.1103/PhysRevLett95.237001). The researchers relied on the resources of the National Center for Computational Sciences at Oak Ridge National Laboratory, and show that a purely electronic model successfully describes superconductivity in high-temperature superconductors (HTSCs).

No Losers?

Superconducting materials conduct electricity without loss because they do not resist the flow of electrical current. (Resistance losses waste much of the electrical power distributed through existing power lines and transformers.) Low-temperature superconductors have been well understood for half a century, but they superconduct only at temperatures close to absolute zero. HTSCs, on the other hand, conduct electricity without loss at much higher temperatures that are obtainable without great expenditure of power.

HTSCs are expected to be crucial in improving energy efficiency by eliminating distribution losses in power cables and transformers. In fact, high-voltage transmission lines, transformers, and many further complexities in the energy grid are a direct consequence of the need to cope with energy losses in regular conductors. The availability of superconductors for power transmission that operate at room temperature could therefore greatly simplify and stabilize the energy grid.

Many efforts are under way to develop practical high-temperature superconductors for this and other applications. As a prelude to this work, modeling studies are being carried out to explore the fundamental nature of superconductors.

Settling the Debate

The research described here is the first modeling effort that addresses a parameter space appropriate to describe real HTSCs. The researchers used the leadership-class computer resources in the NCCS to solve the 2-dimensional (2D) Hubbard model—the model most widely used to study the physics of high-temperature superconductivity—for clusters of as many as 26 atoms.

The Hubbard model has been studied extensively but never with adequate methods to provide confidence in the results. The winning combination for this research was an algorithm that takes a completely different approach from the approximations conducted before, and processors fast enough to solve the

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equations within a manageable time. The vector processors available in the NCCS and the large memory bandwidth of the NCCS computer were essential.

The results demonstrate that the electron pairing that underlies superconductivity in HTSCs can result from strong electronic correlations rather than lattice vibrations.

Conventional superconductivity (operating at temperatures near zero degrees) is mediated by lattice vibrations. The HTSC community has long argued that a different mechanism enables high-temperature superconductivity, but no one could demonstrate it convincingly. "The model used in this research contains no lattice vibrations. Something not in the model can't be responsible for the superconductivity in the model, so it has to be something else," says Thomas Schulthess, a member of the research team, on the conclusion that electronic correlations underlie the mechanism.

The next stage is to determine the physics that cause the superconducting activity present in the model and add material-specific parameters to elucidate the differences among various types of potentially superconducting materials. Based on these results, researchers will have another tool to identify new materials that superconduct at higher temperatures, enabling breakthroughs in real-world applications that will benefit from highly efficient conduction of electricity!

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